Title

METHOD AND SYSTEM FOR ALLOCATION OF CHANNELISATION CODES IN A CODE DIVISION MULTIPLE ACCESS SYSTEM.

Field of the Invention

The present invention relates generally to radio communications systems, such as cellular communication systems, having mobile radios and a radio network infrastructure. More particularly, the present invention facilitates a method and system for allocation of channelisation codes from code trees in Code Division Multiple Access (CDMA) based radio network systems in an efficient way.

Background of the invention

Down link (DL) transmissions in an implementation of a CDMA system, such as in a Wideband CDMA (WCDMA) system according the current 3rd Generation Partnership Project (3GPP) standard TS 25 series, in particular TS 25.213 (Spreading and modulation (FDD)), are coded using a scrambling code and a channelization code per channel, where each connection between base station and user mobile station may comprise one or more physical channels. The purpose of the scrambling code is to have little interference between transmission in different cells, while the channelization code serves the purpose of limited interference between transmissions in one cell. Each cell is allocated a primary scrambling code and one or more (typically 15 for a WCDMA system) secundary scrambling codes. The secundary scrambling codes are used to create additional code space.

All channelization codes using the same scrambling code are organised in a code tree where two codes on a certain level are spawned

from a code of a higher level (parent code), where the values of these two codes are represented as (C,C) and (C,Ĉ), wherein C is the value of the parent code and Ĉ is the complement value of the parent code. A parent code at the top of the code tree has a certain bitrate. A code spawned from it's parent code has half the bitrate of it's parent code. As all codes are spreaded along the branches of the code tree, a property called "Spreading Factor" (SF) denotes the level of spawned codes, SF 1 for the top level, next SF 2, SF 4, SF 8,.. etc.

Mutual interference between transmissions using the same scrambling code but different channelization codes is very low, while the mutual interference between transmissions using different scrambling codes, but having the same channelization codes is higher.

The physical layer transmissions in WCDMA systems are normally continuous, i.e. there are normally no gaps in the transmission. For the purpose of measuring on the same or another frequency than the current one, WCDMA has introduced Compressed Mode (CPM), as to create a gap in the transmission for deployment of measurements. These measurements are needed to e.g. to evaluate the need for- or execute inter-frequency or inter Radio Access Technology (RAT) handovers.

In CPM the transmission is limited in time, to allow for a period without transmission. However, holding the transmission, even for a short period, would decrease the average bitrate and hence interfere with the service provided to the active channels. For non time-critical data connections a temporary decrease in bitrate would be allowable, but for speech connections or connections with a guaranteed bitrate, a decrease in bit-rate would not be allowed.

State of the art WCDMA systems deploy CPM with the so called "Spreading Factor divide by two" (SF/2) method as to maintain the average bitrate. The CPM SF/2 method reallocates temporary another channelisation code from a so called "alternative" code tree, where the bitrate is doubled by allocating a code from this alternative code tree

which is a predefined code with half the SF of the currently used channel, and where the new code is allocated according to a strict relation. After this reallocation, a gap in the transmission is created, thereby keeping the average bitrate on substantially the same level as before the reallocation. For each primary or secundary scrambling code, there are two alternative scrambling codes deployed for associated alternative code trees, typically denoted by "left" and "right" alternative code tree, dedicated for CPM with SF/2 method.

When deploying CPM with the SF/2 method in prior art WCDMA systems, depending on the original channelisation code, the channel reallocates a channelisation code, having half the SF of the current channelisation code, from either a left or right alternative code tree according to a simple and strict reallocation scheme.

The scrambling code that is used in the alternative code trees is a different scrambling code than the one used for the primary code tree. By doing so, the relatively simple and strict relation between the channelization codes for a CPM user deploying the SF/2 method is not disturbed.

In cases where a decrease in average bitrate is allowed, CPM methods known as "Higher Layer Scheduling (HLS)" and "puncturing" are deployed. In these CPM methods channelisation codes are not reallocated and the effects of decrease in bitrate are handled on a higher level.

It must be realised that channelization codes are a limited resource within a code tree. A new request for a channelization code, allthough preferred, may not be possible on the primary code tree. In such case it is possible to allocate a channelisation code from a secundary code tree.

According to e.g. references "Code Placement and Replacement Stategies for Wideband CDMA OVSF Code Tree Management" by Yu-Chee Tseng, Chih-Min Chao & Shih-Lin Wu, and OVSF CODES ASSIGNMENT AND REASSIGNMENT AT THE FORWARD LINK OFW-CDMA 3G SYSTEMS" by Angelos N.

Rouskas and Dimitrios N. Skoutas, wellknown code placement methods, like "always left", "crowded first", or "random" are applied as allocation strategies for new channels having the general objective to make the code tree as compact as possible in order to support new calls, either with less blocking or with less reasllocation costs.

However these prior art solutions would in case of (partly) occupied code trees in most cases violate the strict relation between the old and new channelisation codes when reallocating channelisation codes for a CPM user, deploying the SF/2 method. Hence these known methods methods could either cause a complex administration of reallocation of channels in case of CPM with the SF/2 method or require more secundary code trees in order to cope with said simple and strict reallocation scheme.

One skilled in the art will recognise that replacing of channelisation codes without a simple and strict scheme could introduce the occurrance of additional delay and a possibility of a lost connection.

In state of the art solutions of WCDMA systems several scrambling codes, typically 3 to 4, can be used at the same time. However the larger the number of simultaneously used scrambling codes the larger the mutual interference, hence resulting in a decreased capacity of the WCDMA system.

Summary of the Invention

It is an object of the present invention to provide an improved method of performing radio communication within a CDMA based system, operating with connections that use at least one CPM method which requires reallocation of channelisation codes, such as SF/2, in a manner that signal interference caused by simultaneously deployed scrambling codes is reduced.

It is a further object of the present invention to provide a radio communication system, arranged for deploying WCDMA, in accordance with the improved method of the invention.

These and other advantages are achieved by the present invention in a method of performing allocation of channelisation codes to channels in a Code Division Multiple Access (CDMA) system having the channelisation codes organised in a primary and zero or more secundary code trees, where each of the code trees has zero or more alternative code trees, each code tree having one or more channelisation codes per spreading factor, where the channelisation codes are according to their position in the code tree denoted consecutively by a code index with a lowest to a highest value per spreading factor within each code tree, and where the system deploys any combination of channels which may operate in a first Compressed Mode (CPM) type requiring temporary reallocation of channels to a channelisation code with a lower spreading factor, and channels according to a second CPM type, which do not require reallocation, and where the channel according to the first Compressed Mode type is allocated a channelisation code with a lowest code index out of a group of free channelisation codes for a certain spreading factor, and a channel according to the second Compressed Mode type is allocated a channelisation code with a highest code index out of the group of free channelisation codes for a certain spreading factor.

The method according to the present invention is based on the insight that reallocating channels during CPM, such as required for a SF/2 method, could be executed efficiently and with a reduced number of alternative code trees, if the allocation of new channelisation codes from a code tree is taking into account the type of CPM method to be deployed for the channel, when executing an allocation of a channelisation code for a channel.

During allocation of new channelisation codes, channels that deploy a CPM method which needs reallocation (such as SF/2), are

allocated starting from the outer branches at one side of the primary (or secundary) code tree, and channels that deploy a CPM method which need no reallocation (such as HLS or puncturing), are allocated starting from the outer branches at the opposite half of the code tree.

When CPM has to occur, a channel that deploys a CPM method which needs reallocation, is reallocated to its parent channelisation code within an alternative code tree, which code tree is related the primary (or secundary) code tree where the original channelisation code resides. During CPM the original channelisation code is reserved and will be re-occupied by the same channel again when the CPM period has ended.

The method of the invention may be deployed within a state of the art implementation of CDMA, such as WCDMA, without adaptions to the WCDMA standards on channelisation code re-allocation during CPM with the SF/2 method.

In a further embodiment of the method, according to the invention, channels which deploy a CPM method which does not require reallocation, such as HLS or puncturing, allocate channelisation codes, associated to channelisations codes for HLS in the primary (or secundary) code tree, from an alternative code tree.

These and other embodiments according to the present invention are now illustrated in more detail with reference to the enclosed drawings.

Brief Description of the Drawings

Fig. 1 presents a schematic diagram of a code tree of a CDMA system, as implemented by a WCDMA system, showing channelisation codes;

Fig. 2 presents a diagram of primary and secundary code trees with their respective alternative code trees;

Fig. 3 presents a diagram of a code trees according to the

invention.

Detailed Description

Without restrictions to the scope of the invention, in order to provide a thorough understanding of the present invention, the invention is presented against the background and within the scope of the current implementation of CDMA systems by e.g. a WCDMA system according to the current 3rd Generation Partnership Project (3GPP) standard TS 25 series, in particular TS 25.213. However, the present invention may be employed in any context where there is a system deploying a generic CDMA protocol.

In state of the art implementations of CDMA systems, such as WCDMA systems, the scrambling codes are Gold codes. Each cell is allocated a primary scrambling code and 15 secundary scrambling codes. The secundary scrambling codes are used to create additional code space.

Fig. 1 illustrates schematically a code tree within a WCDMA system. The channelization codes are Orthogonal Variable Spreading Factor (OVSF) codes. All channelisation codes using the same scrambling code are part of the same code tree. The Spreading Factor (SF) determines the rate of the channel. Each "parent" channelisation code has two "children" with a doubled SF. Any channelisation code in the code tree can only be allocated when no channelisation codes in its branch are allocated. So none of the (grand)children or (grand)parent of an allocated channelisation code may be allocated as well from the same code tree.

The root code of the code tree is denoted by $C_{ch\ 1,0}$ with logical value (1), where this root code as well as other OVSF codes are denoted as $C_{ch,SF,k,}$ wherein "C_{ch}" is the channelisation code with index "$_{SF}$" for the spreading factor (SF) and index "$_{k}$" for the code index (or branch nbr), where $0 \le k \le SF-1$. The channelisation codes on each subsequent lower level with respect to the parent code are denoted by $C_{ch\ SF*2,((n+1)*2)-2}$

and $C_{ch\ SF*2,(n+1)*2-1,}$ where the code values are defined by spawning two codes values (C_{ch},C_{ch}) and $(C_{ch},\hat{C}_{ch})$ of the parent code, where $\hat{C}_{ch}$ denotes the complement value of C_{ch}. For each lower level the Spreading Factor SF is doubled, just as the number of codes by spawning two codes from a parent code, hence the number of codes for a certain SF is equal to the SF. The parent code has the highest bit rate BR. The codes at the lower level (hence with a higher SF) have a lower bit rate, equal to BR/SF.

The mutual interference between transmissions using the same scrambling code but different channelization codes is very low, while the mutual interference between transmissions using different scrambling codes, but having the same channelization codes is higher.

The physical layer transmissions in WCDMA are normally continuous, i.e. there are normally no gaps in the transmission. For the purpose of e.g. measurement and execution for inter frequency and inter RAT handovers, gaps in the transmission are created as to have a transmission free period, wherein e.g. measurements on a same or other frequency/code than the current one can be made. The WCDMA implementation of CDMA has introduced the term "Compressed Mode" (CPM) for the mode wherein the system is operating when these transmission gaps are created.

During CPM the transmission is limited in time, to allow for a time without transmission. There are two main methods for deploying CPM: Spreading Factor decrease by 2 (SF/2) and Higher Layer Scheduling (HLS). A third alternative called puncturing also exists but is less used. In the scope of this invention the puncturing method is completely equal to HLS.

Summary of the known techniques for creating gaps in transmission:

i) CPM with SF/2 method steps up one level in the code tree (e.g. from SF = 128 to SF = 64). By doing so the bit rate is doubled, so only half the time is required to transmit the same amount of data.

ii) When deploying CPM with HLS method, the application

data is scheduled (delayed) such that a lower peak rate results. So only a part of the time is required to transmit the data.

iii) When deploying CPM with puncturing method, physical layer information is punctured, decreasing the coding rate, i.e. the protection is decreased.

When deploying CPM with SF/2 method a channelization code with a higher bit rate than currently used needs to be allocated. There is a strict relation, according to the WCDMA standard, between the currently allocated channelization code and the channelization code that shall be used during CPM. The new channelisation code is a parent of the current channelisation code in an alternative code tree using an alternative scrambling code, where no other channelisation codes may be allocated from the sub code tree under this parent.

Fig. 2 illustrates schematically primary and secondary code trees with their respective related alternative code trees within a WCDMA system.

In prior art there are two alternative scrambling codes reserved for each primary or secondary code tree for CPM with SF/2 method, denoted as a "left" alternative code tree and a "right" alternative code tree. There are two alternative code trees reserved for CPM with SF/2 method at each primary or secondary code tree, where a strict relation between the original and reallocated channelisation codes must be maintained, resulting in a allocation within either the left or right alternative code tree, dependent on the original channelisation code at the primary or secondary code tree.

The strict relation, referred to in the preceding description, is presented here where channelisation codes are denoted as $C_{ch,SF,k,}$ $0 \leq k \leq SF-1$. During CPM deploying the SF/2 method, the reallocated channel has a channelisation code $C_{ch,SF/2,k}$ on the left alternative code tree if original $k < SF/2$. During CPM deploying the SF/2 method, the reallocated channel has a channelisation code $C_{ch,SF/2,k-SF/2}$ on

the right alternative code tree if original k ≥ SF/2.

From the state of the art scheme presented above it is clear that for CPM with the SF/2 method, channelisation codes are reallocated to either the left or right alternative code trees, depending on its original location at the primary or secondary code tree.

Channelization codes are a limited resource. A new request for a channelization code may not be possible on the primary code tree. In such case it is possible to allocate codes from a secondary code tree with a scrambling code different from the primary code tree scrambling code.

In the state of the art solutions of CDMA systems such as WCDMA systems several scrambling codes, typically 3 to 4, can be used at the same time. However the larger the number of used scrambling codes the larger the mutual interference. This results in a decreased capacity.

With the invention, the number of used scrambling codes is reduced without violating the simple but strict relation for reallocation of channelisation codes of channels deploying CPM with SF/2 method. Using less scrambling codes, leads to lower mutual interference and hence to an increased capacity of the WCDMA system.

As a result of the issues stated above, it is to be regarded as advantageous to use as few scrambling codes as possible.

Fig. 3 illustrates schematically a set of code trees, where a primary (and one or more secondary) code tree together with its two related alternative code trees is depicted for use within a WCDMA system according to the invention. Code indexes for a SF = 8 are depicted, where the SF is arbitrary chosen for explanation of the invention.

As a solution for decreasing the mutual interference within a WCDMA system and hence increasing the capacity of the system, all channels that deploy a CPM method that requires reallocation (such as SF/2) are allocated starting from the outer branches at one side of the code tree and the channels that deploy CPM without the need for

reallocation (such as HLS or puncturing) are allocated starting from the outer branches at the opposite side of the code tree.

The figure illustrates as an example, channels that deploy a CPM method that requires reallocation (such as SF/2) are allocated starting from the left side (or half) of the primary (or secondary) code tree with a lowest code index nbr 0, and channels that deploy CPM without the need for reallocation (such as HLS or puncturing) are allocated starting from the right side of the primary (or secondary) code tree with a highest code index nbr 8.

According to the invention, the method for allocating a channel is presented according to the following steps:

- determine the type of CPM of the channel which is to be allocated a channelisation code;

- when allocating a channelisation code for a channel that deploys CPM that needs reallocation (e.g. SF/2 method), select the available code with the <u>lowest</u> code index, hence starting from the left side of the primary (or secondary) code tree;

- when allocating a channelisation code for a channel that deploys CPM which does not need reallocation (e.g. using HLS method), select the available code with the <u>highest</u> code index, hence starting from the right side of the primary (or secondary) code tree.

One skilled in the art will understand that using the left- or right side, represented respectively by lowest- and highest code indexes, of the code tree will be arbitrary as long as the two distinguished CPM type channels are located starting at opposite outer branches of the code tree.

According to this method, channels deploying CPM which need reallocation (such as SF/2) will, according to the strict reallocation rules presented above, only be reallocated to the left alternative code tree as long as the original location resides in the left side of the primary (or secondary) code tree, hence only one alternative code tree

for these reallocated channels is in use.

As a result of the code placement according to the invention, when there are sufficient codes available for normal traffic, in most practical cases only two code trees (a primary and its left alternative) instead of three code trees will be in use.

As a further embodiment of the invention, that further exploits the benefit of allocating less code trees, the general concept is represented by the insight that: when normal mode traffic requires a secondary code tree, allocate channels that deploy CPM without the need for reallocation (such as HLS) to channelisation codes on an alternative code tree, associated to codes that are currently in use for HLS channels in the primary (or secondary) code tree.

In case of code shortage, channels which deploy CPM without need for reallocation (such as HLS), share an alternative code tree with normal mode users, decreasing the number of code trees in use (in most practical cases from four to three, hence one primary and two alternative code trees). This further embodiment again decreases the mutual interference, and therefore increases the capacity of the system.

As CPM might be frequently deployed in cells at the edge of the CDMA network coverage, the existence of alternative code trees is regarded as frequent as well. In case of code shortage at a primary code tree, a creation of a secondary code tree, while alternative code trees with free codes exists, is to be regarded as waste of code space.

Below this further embodiment of the method is described for the cases that a new channel requires a channelisation code where this new channel deploys CPM either with a need for reallocation (such as SF/2) at paragraph A or without a need for reallocation (such as HLS) at paragraph B.

Par. A)

A method to allocate new channels which deploy a CPM method which needs reallocation, such as SF/2, comprise the following steps:

- create a candidate list of channelisation codes in the primary (or secondary) code tree which are free and not reserved;

- a channelisation code on this list, having a corresponding parent code at the associated alternative code tree which is not free is excluded from the candidate list;

- if more than one candidate exists in the primary (or secondary) code tree, select a candidate with a lowest code index, hence from the left side of the code tree, on the primary (or secondary) code tree;

- if there exist no candidate on the primary (or secondary) code tree try to reallocate a HLS type channel from the primary (or secondary) code tree to an alternative code tree to free space on the primary (or secondary) code tree for the new channel;

- if insufficient free space can be created through reallocation of HLS type channels, the new channel is allocated a channelisation code from a new secondary code tree.

Par. B)

A method to allocate new channels which deploy a CPM method which do not need reallocation, such as HLS, comprise the following steps:

- create a list of candidate channelisation codes in the primary (or secondary) code tree which are free and not reserved;

- if more than one candidate channelisation code exists, select the code with the highest code index from said list;

- if no candidate channelisation code at the primary (or secondary) code tree exists create a list with candidate channelisation codes at a right side alternative code tree related to the primary (or secondary) code tree, which codes must be free and not reserved, with the restriction that the same channelisation code at the related primary (or secondary) code tree must be used by a channel that uses HLS in case of CPM;

- if more than one candidate channelisation code exists, select the code with the <u>highest</u> code index from said list;

- if still no candidate channelisation code at the right alternative code tree exists create a list with candidate channelisation codes at a left alternative code tree related to the primary (or secondary) code tree, which codes must be free and not reserved, and the same channelisation code at the primary code tree must be used by a channel that uses HLS in case of CPM;

- if more than one candidate channelisation code exists, select the code with the <u>highest</u> code index from said list;

- if no candidate channelisation code at the left alternative code tree exists, the channel is allocated a channelisation code from a new secondary code tree.

The method presented above is deployed in a CDMA system, e.g. a WCDMA system as implementation of CDMA, comprising mobile user equipment, radio base stations RBS, radio base station controllers (RBC) and radio network controllers (RNC). The method presented above may be executed in the RBS, RBC or RNC, where at least one of these entities has electronic equipment such as processing units, I/O circuitry and memory, configured to select and allocate channelisation codes, create and store lists, reallocate channels, determine the CPM type of the channel and apply the signalling between the elements requesting for allocation of a channelisation code to a channel and the elements performing the allocation of a channelisation code to a channel.

By improving the system capacity as a result of less mutual interference by the reduced number of code trees, the method of the invention contributes to system benefits for the operator of such a system.

A higher number of code trees simultaneously in use will increases the output power of a base station, hence the invention provides a CDMA communication system with increased capacity, compared to

prior art systems.